New Tagger Hodoscope for the INSIGHT-Experiment at ELSA

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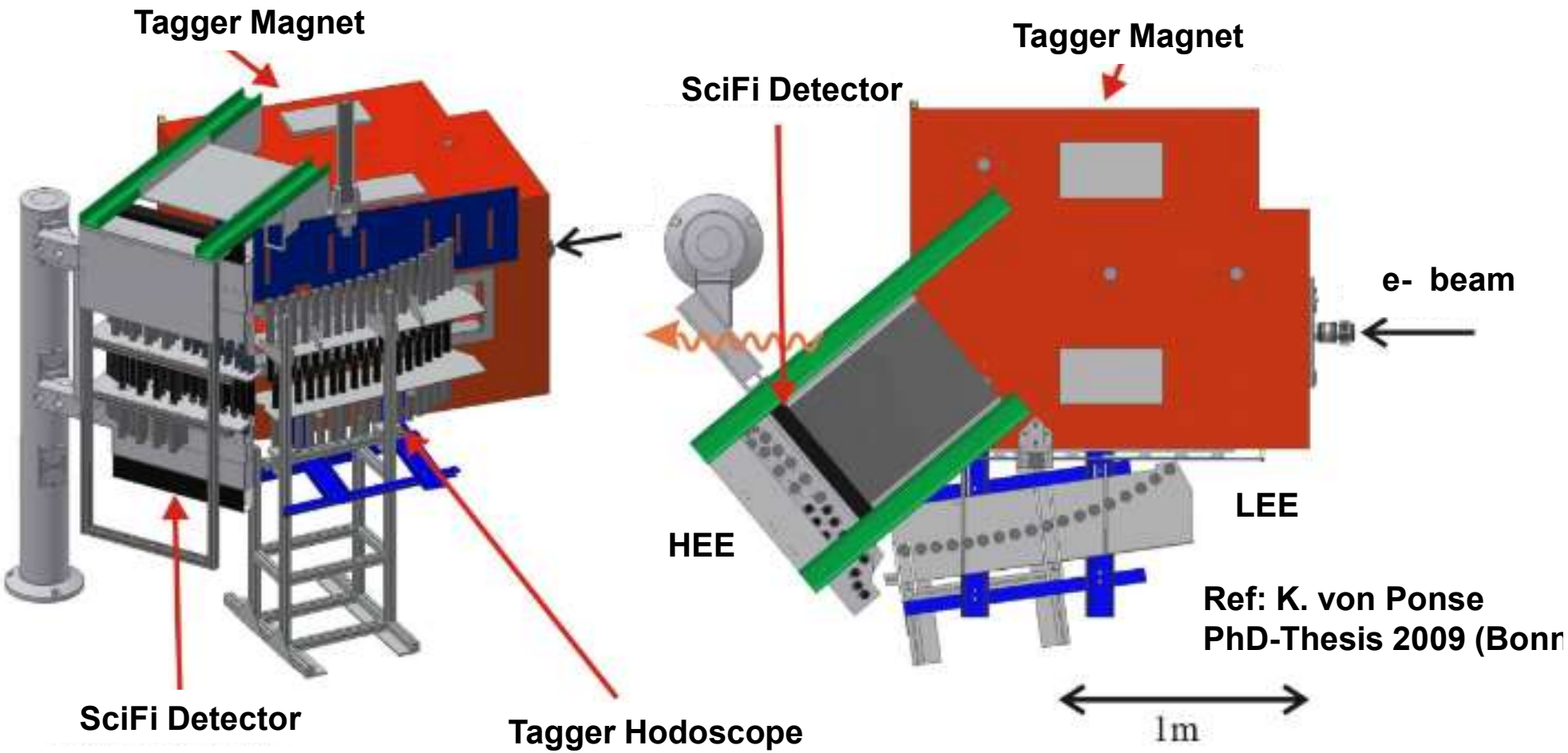
Photon Tagging System at ELSA



High rates 1 MHz for scattered electrons

Time resolution in the order of 0.5 ns (FWHM)

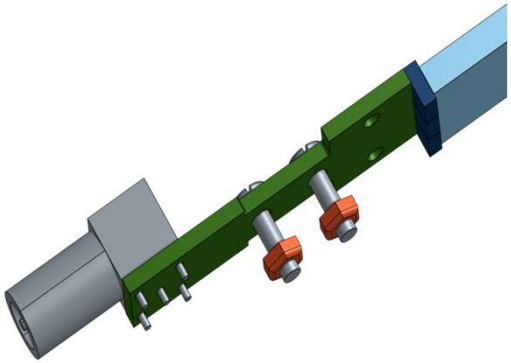
96 scintillator bars (BC404)with PM readout
1 cm to 5 cm detector width

SiFi detector at high electron energy range (HEE)

New detector with time resolution in the order of 50 ps for the INSIGHT experiment

New Photon Tagging Detector

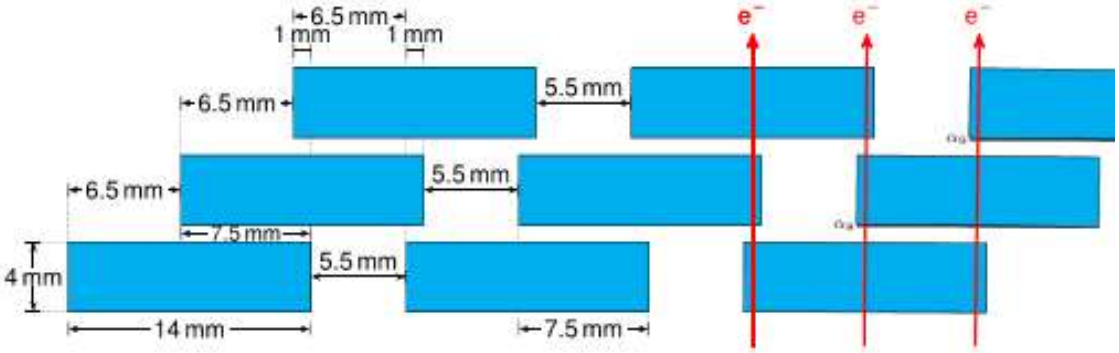
Use scintillator strips with modern SiPM's



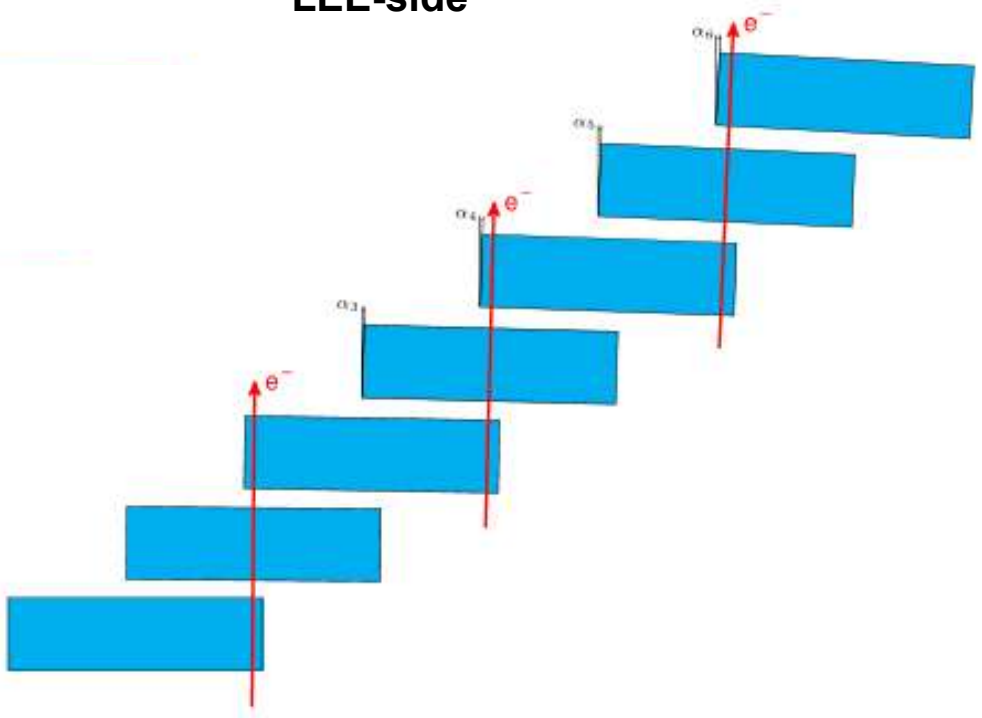
<u>New detector for the tagging system:</u>

Material: BC422 scintillator
Size: 100mm x 14mm x 4mm
SiPM: Broadcom AFBR-S4N44C013 SiPM

HEE-side



LEE-side



- full overlap of detectors (>= 2 det. per e- hit)
  improve energy resolution at the LEE side

- perpendicular hit of e-

- 271 single scintillator strips

New Photon Tagging Detector

New detector for the tagging system:

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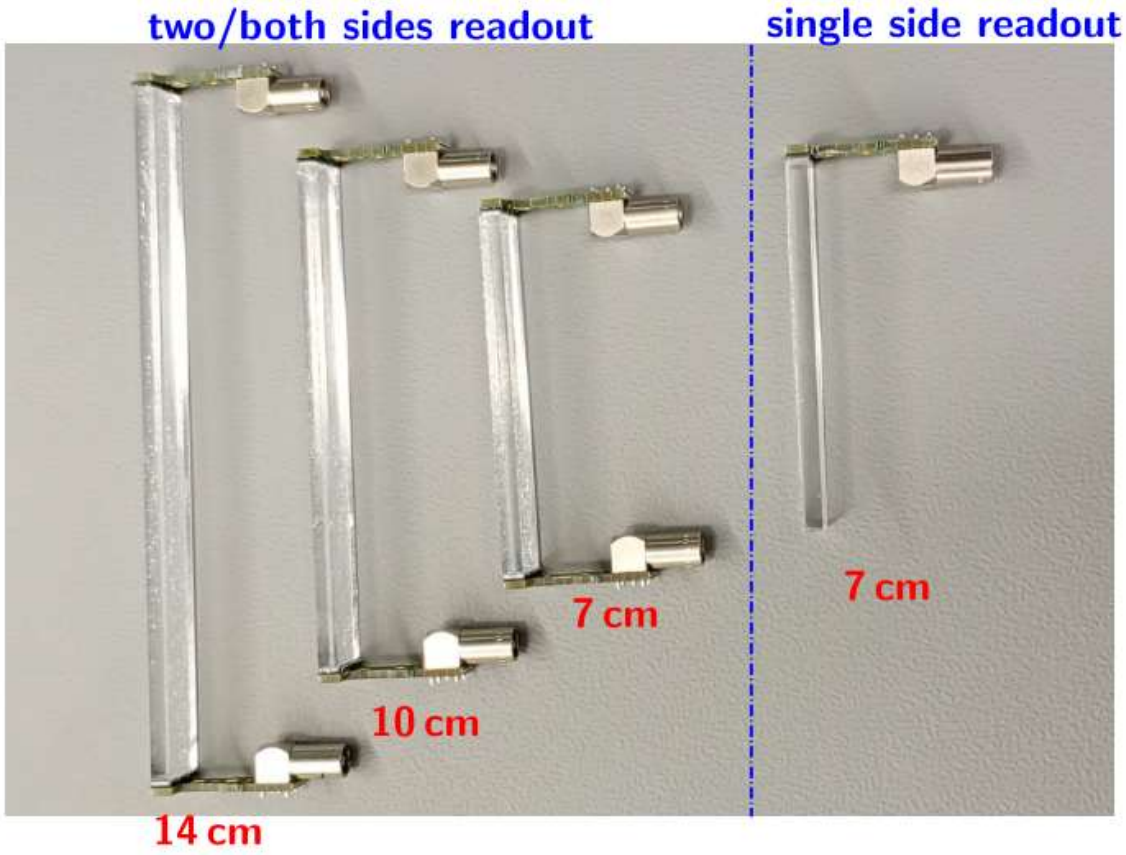
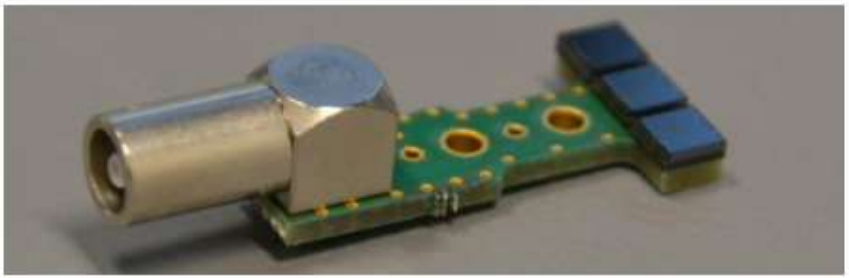


C.Tezel, FTD electronic workshop



- 3 SiPMs in series
- $U_{SiPM} = 96\,V - 147\,V$

Ref: P. Rosinsky Master-Thesis 2025 (Bonn)

New Photon Tagging Detector

Time resolution for scintillators with SiPM readout

Ref: S. Gundackert and P. Lecoq (CERN)

$$\sigma_{min} \propto \sqrt{\frac{\tau_d \cdot \left(1.57 \cdot \tau_r + 1.13 \cdot \sqrt{{\sigma_{PTS}}^2 + {\sigma_{SPTR}}^2}\right)}{LY \cdot PDE}}$$

scintillation material:

- $\tau_{d,r}$: decay/rise time detector
- **LY:** **L**ight **Y**ield per unit energy

SiPMs:

- **PDE:** **P**hoton **D**etection **E**fficiency
- σ_{PTS}: **P**hoton transfer **T**ime **S**pread (std.dev.)
- σ_{SPTR}: **S**ingle **P**hoton **T**ime **R**esolution (std.dev.)

Improving σ:

- $\downarrow \tau_d, \tau_r$
- $\downarrow \sigma_{PTS}, \sigma_{SPTR}$
- $\uparrow$ **PDE**, LY

New Photon Tagging Detector

Different scintillator materials:

Names		Description	τ_{rise}/ns	τ_{decay}/ns	LO/%	γ/MeV
EJ-204	BC-404	use with green WLS	0.7	1.8	68	10 400
EJ-228	BC-418	very fast timing (<10 cm)	0.5	1.2	67	10 200
EJ-230	BC-420	EJ-228, for >10 cm	0.5	1.3	64	9 700
EJ-232	BC-422	very fast timing (<10 cm)	0.35	1.6	55	8 400
EJ-232Q	BC-422Q	ultra-fast timing – (0.5 %)	0.11	0.7	19	2 900

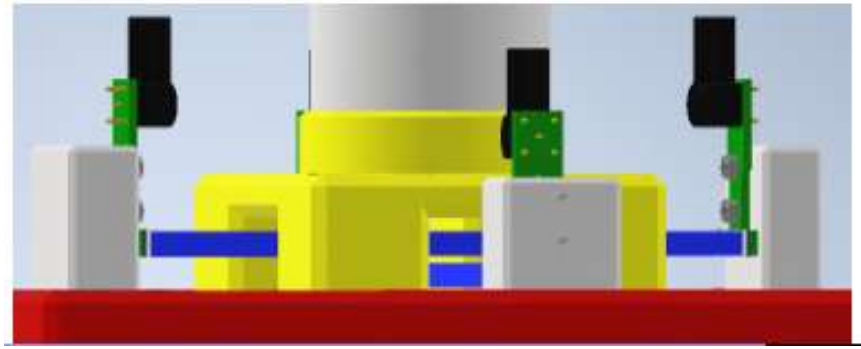
Different silicon photomultipliers (SiPM):

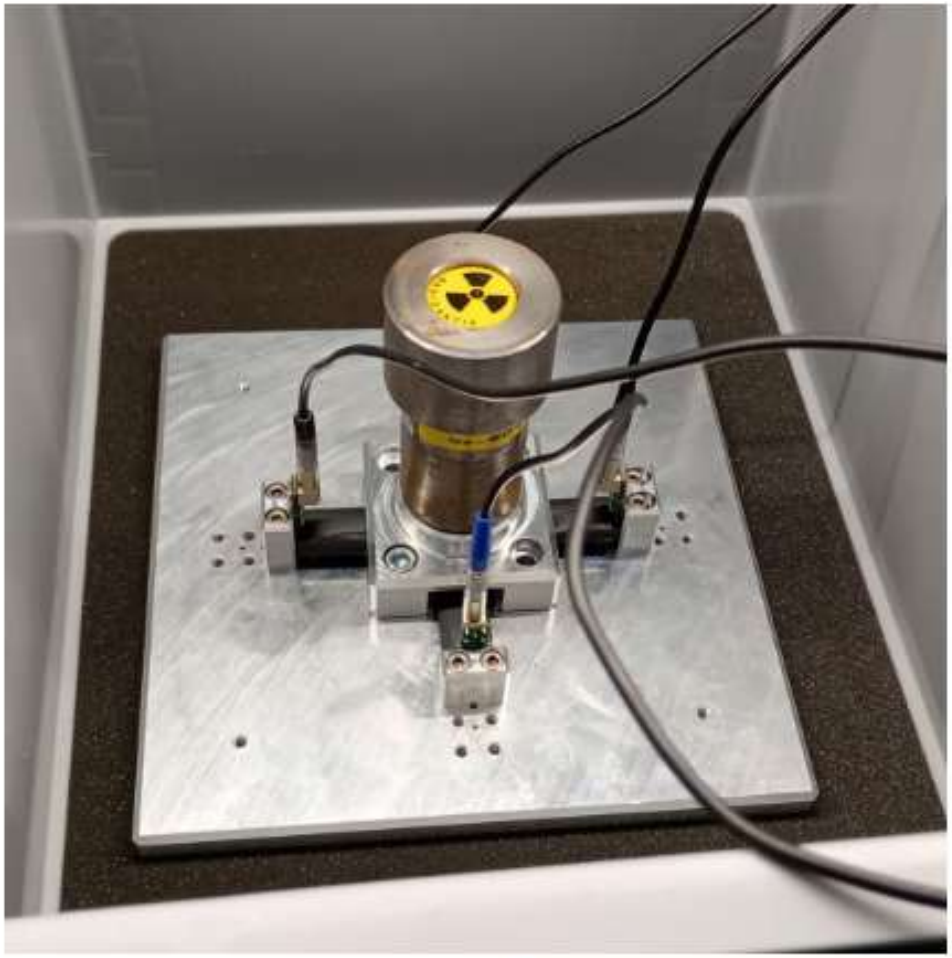
- **Broadcom SiPM** with high PDE (65%) and small SPTR time (100ps)
- **Hamamatsu SiPM**

Detector Test Setup

components:

- ground plate
- table
- collimator with ^{90}Sr
- detector with PCB board
- blocks (holding detector)
  - different heights
  - → upper/lower detector

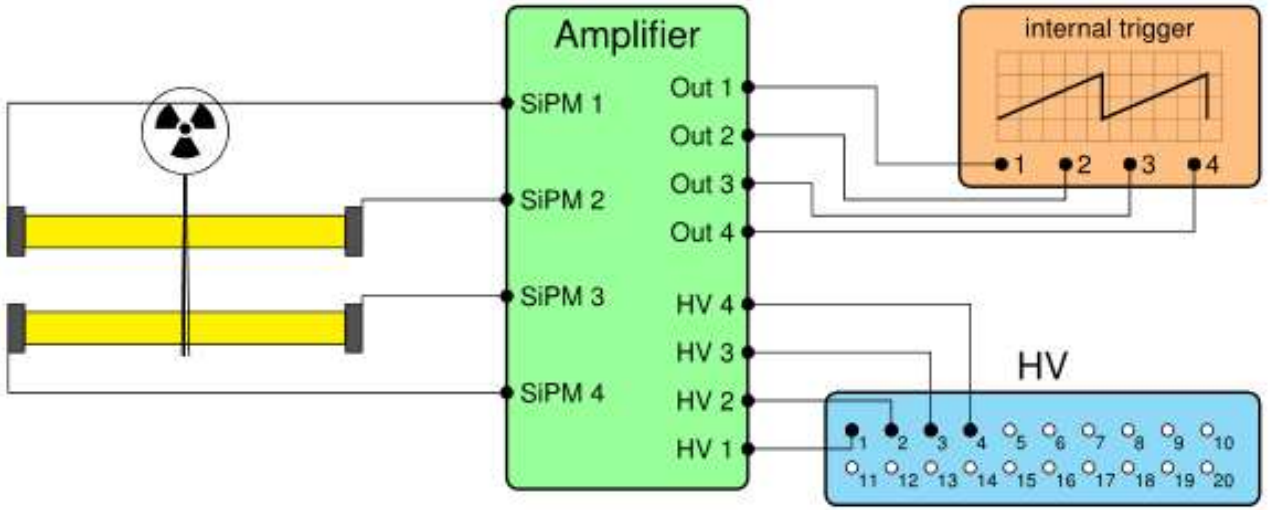




Two test setups : Bonn (P. Rosinsky, M. Lang, P. Hurck)
Bochum (F. Afzal, V. Willing)

Ref: P. Rosinsky Master-Thesis 2025 (Bonn)

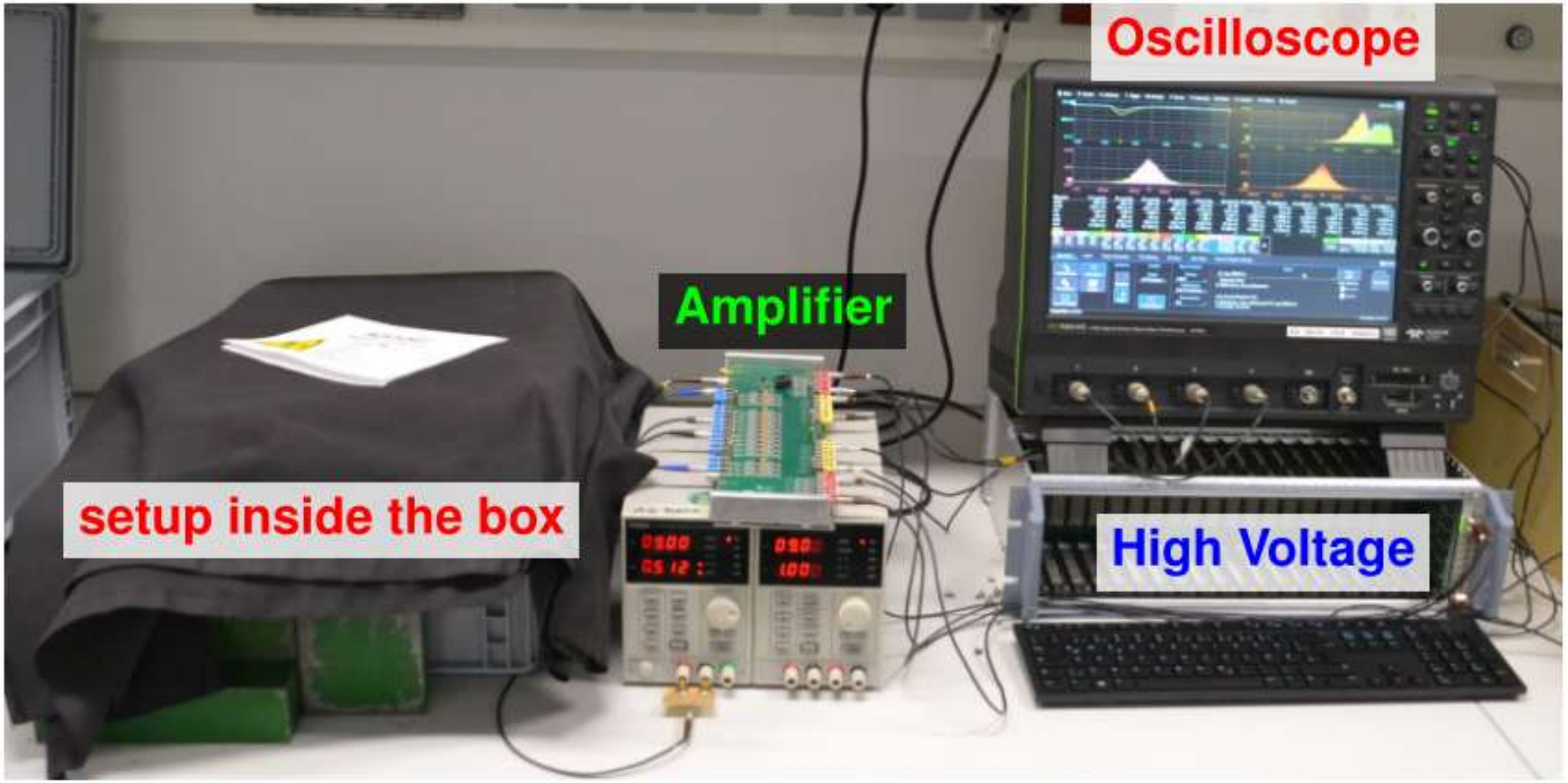
Detector Test Setup



- detectors + SiPMs
- Amplifier from PSI & Tel Aviv University [11]
- HV unit from PSI (CH) – not commercialized
  20ch with 0–300 V DC, 1 mA
- Scope for readout
- Scope prior analysis
  → histograms (e.g. for Δt)
- trigger: coincidence
  (in scope)

Ref: P. Rosinsky Master-Thesis 2025 (Bonn)

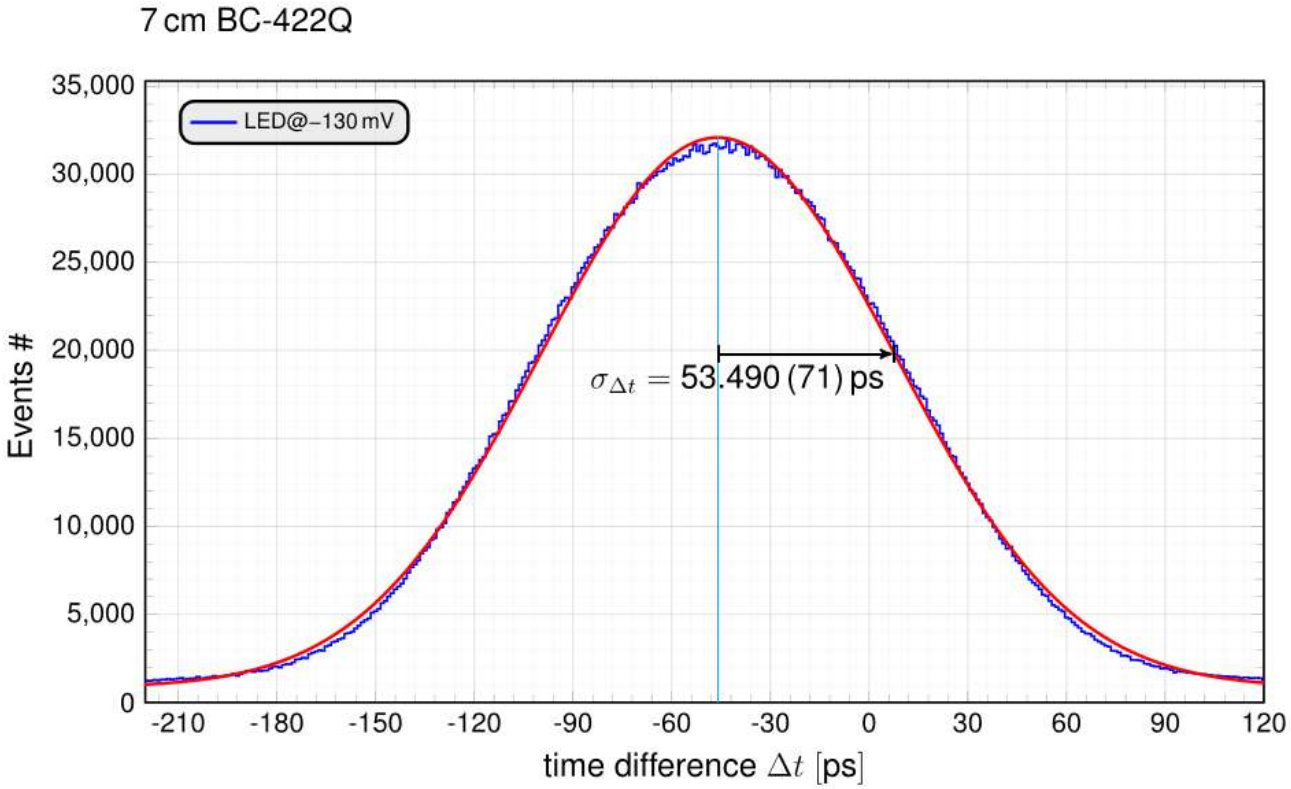
Detector Test Setup



Ref: P. Rosinsky Master-Thesis 2025 (Bonn)

First Results

Material	length	U_{over}/V	$\sigma_{\Delta t}$/ps	σ_{avg}/ps
BC-422	70 mm	12	62.26(35)	31.13(18)
BC-422	100 mm	12	71.15(37)	35.58(19)
BC-422	140 mm	12	82.37(23)	41.19(12)
BC-422Q	70 mm	12	53.490(71)	26.745(36)
BC-422Q	4 mm	12	35.860(37)	17.93(19)



σ_{avg} = 27 ps

Results and Outlook

R&D on scintillator material and SiPM's: BC422Q and Broadcom SiPMs, close to finalize

HV units for SiPM's: PSI design, successful tests, ready to order

Important next steps:

Amplifier: PSI design has to be adapted to our final detector design
together with the FTD electronic workshop

Full tagger simulation :

Design new holding structure: together with FTD and mechanical workshop

Protype of 20 channel : Final holding structure, final amplifier with new readout system,
prototype test on an electron beam

Spare Transperencies

Time Resolution

Here: Measuring time difference $\Delta t \rightarrow \sigma_{\Delta t}$

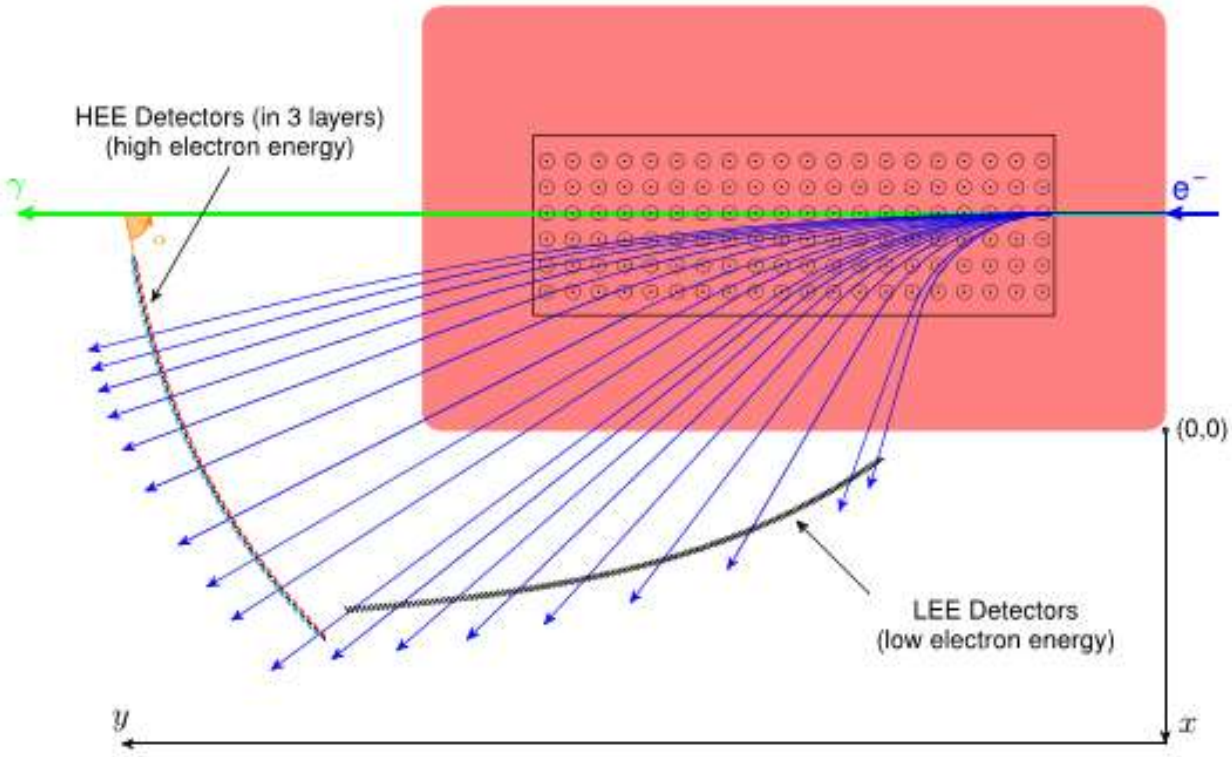
$$\begin{aligned} \Delta t &= t_1 - t_2 \\ \sigma_{\Delta t} &= \sqrt{\sigma_{t_1}^2 + \sigma_{t_2}^2} \overset{\sigma_{t_1}=\sigma_{t_2}=\sigma_t}{=} \sqrt{2} \cdot \sigma_t \end{aligned}$$

σ_t: time res "per SiPM"

final experiment (average for time-point)

$$\begin{aligned} \bar{t} &= \frac{t_1 + t_2}{2} \\ \sigma_{\bar{t}} &= \frac{1}{2}\sqrt{\sigma_{t_1}^2 + \sigma_{t_2}^2} = \frac{\sigma_t}{\sqrt{2}} = \frac{\sigma_{\Delta t}}{2} \end{aligned}$$

New Tagging Detector



- keep or improve energy resolution
- aim: $\sigma \leq 100\,\text{ps}$
- 271 detectors
- width 14 mm, thickness 4 mm
- LEE: in a curved row
- HEE: 3 layers $\rightarrow$ full overlap

Scattered Electron Beam Profile